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Optical Property Measurements as a Diagnostic Tool for Control of Materials Processing in Space and on Earth

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ABSTRACT

One of the major science justifications for containerless processing of materials in microgravity is the possibility of developing new and exciting materials through high temperature processing via the liquid state. The lack of convection produces quiescent melts enabling undercooling, glass formation and other interesting phenomenon to occur readily. However, methods for following, controlling and measuring processing parameters are not fully developed at this time. In this paper, we describe a new method, including results, to measure, control and follow containerless processing in ground based levitators.

This new technique enables instantaneous optical property measurements from a transient solid or liquid surface concurrent with true temperature measurement. This has been used succesfully as a diagnostic tool to follow processing of aluminum, silicon and titanium during electromagnetic levitation. Experiments on aluminum show the disappearnce of the oxide (emittance 0.33) at ca. 1300 C leaving a liquid surface with an emittance of 0.06. Electromagnetic levitation of silicon shows a liquid with a constant emittance (0.2) but with a solid whose emittance decreases very rapidly with increasing temperature. Consequently, the processing of materials at high temperatures can be controlled quite well through the control of surface optical properties. Candidate materials will be described and science justifications will be presented.

RESULTS: The first figure illustrates the change in polarization that occurs on reflection from a surface and also the design of a laser polarimeter in the case of a levitated droplet. The second figure summarizes the experiments that illustrate the versatility of the laser polarimetric technique as a diagnostic tool in containerless processing. The third figure shows the temperature dependence of the spectral emissivity for clean liquid aluminum while the fourth slide compares the data obtained in our levitation experiments for solid and liquid silicon with those in the liqterature. The last figure shows oxide formation and removal in the case of iridium illustrating that laser polarimetry is sensitive to changes in surface chemistry and physics.

CONCLUSION: It has been clearly demonstrated that laser polarimetry is a fast, reproducible technique that allows process chemistry and physics to be monitored and controlled. Intersonics is currently developing the Division of Amplitude Polarimetric Pyrometer (DAPP) for accurate temperature and emissivity measurement.

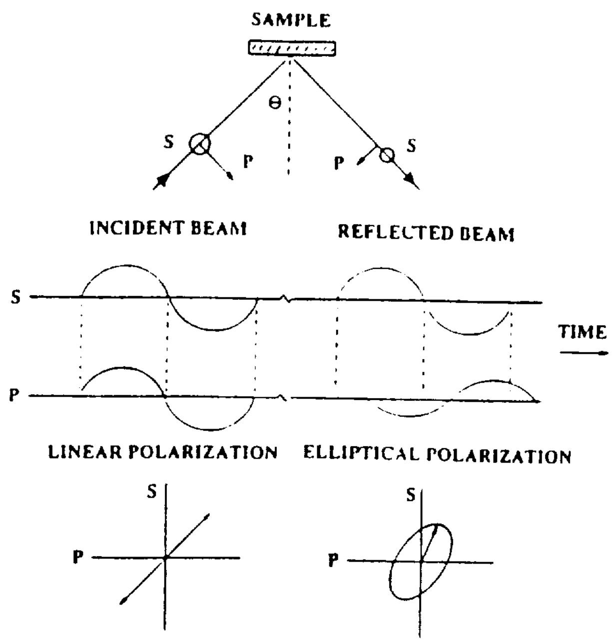


Figure 4.1 Illustration of change in amplitude and phase of reflected light.

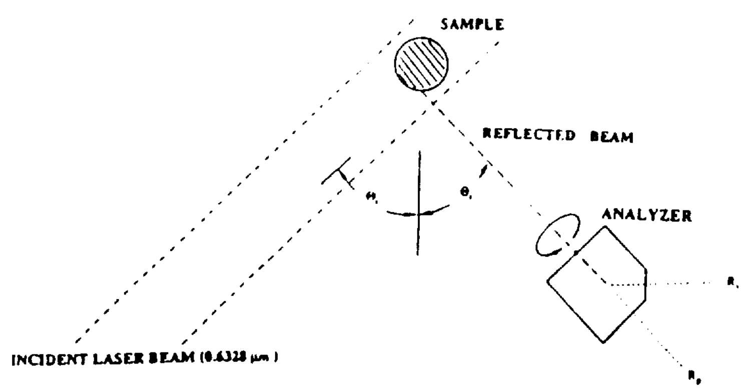


Illustration of Rotating Analyzer Ellipsometry

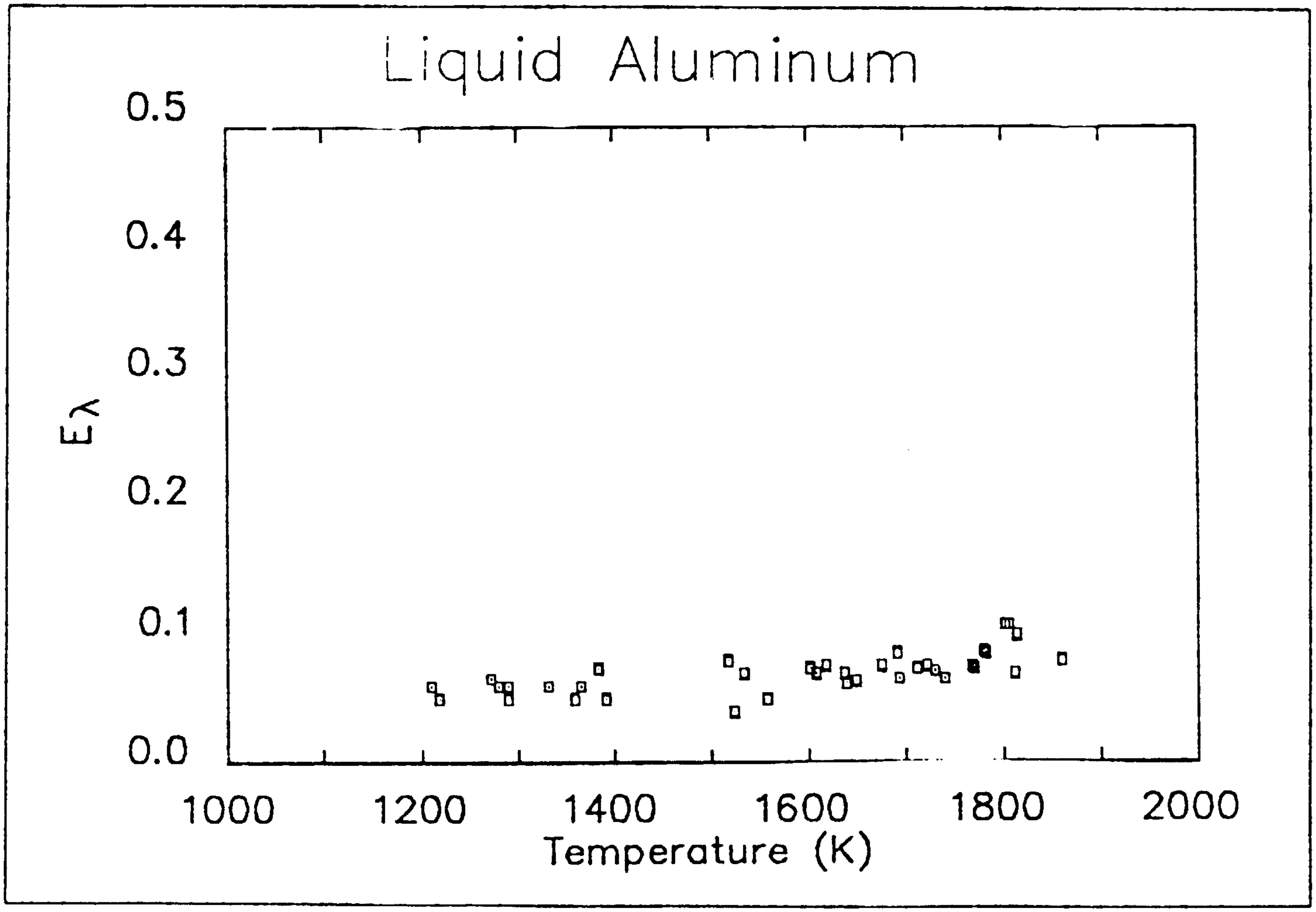
SUMMARY

* LASER POLARIMETRY IS FAST, REPRODUCIBLE, AND EXACT METHOD TO MEASURE THE OPTICAL PROPERTIES OF MATERIALS AT HIGH TEMPERATURES IN CONTAINERLESS EXPERIMENTS.

* IT HAS BEEN USED TO FOLLOW:

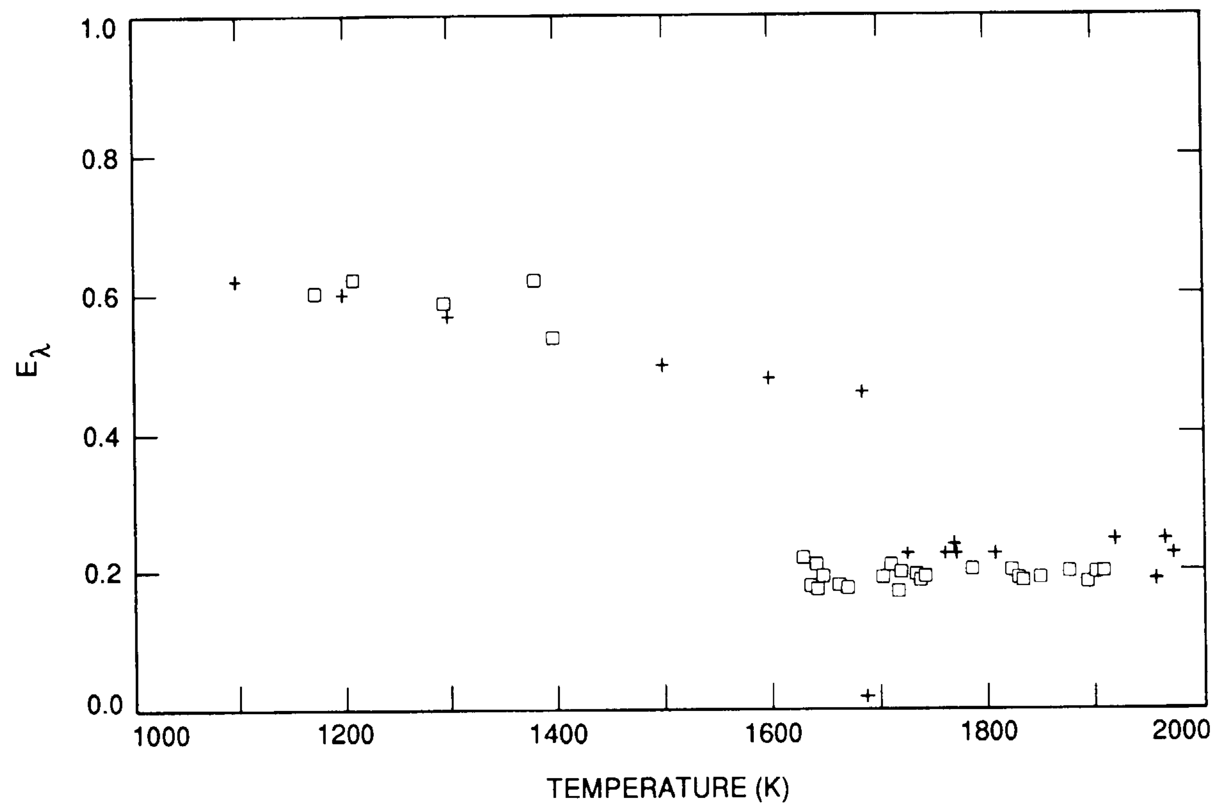
  a OXIDATION — Ir, B
  b PHASE TRANSFORMATION — Hf
  C MELTING, UNDERCOOLING — Nb, Pt, Pd, Si
  d BAND STRUCTURE CHANGES — Cu, Au, Pd

* DIVISION OF AMPLITUDE POLARIMETRIC PYRAMETER (DAPP) IS BEING DEVELOPED FOR MICROGRAVITY APPLICATIONS BY INTERSONICS INCORPORATED.

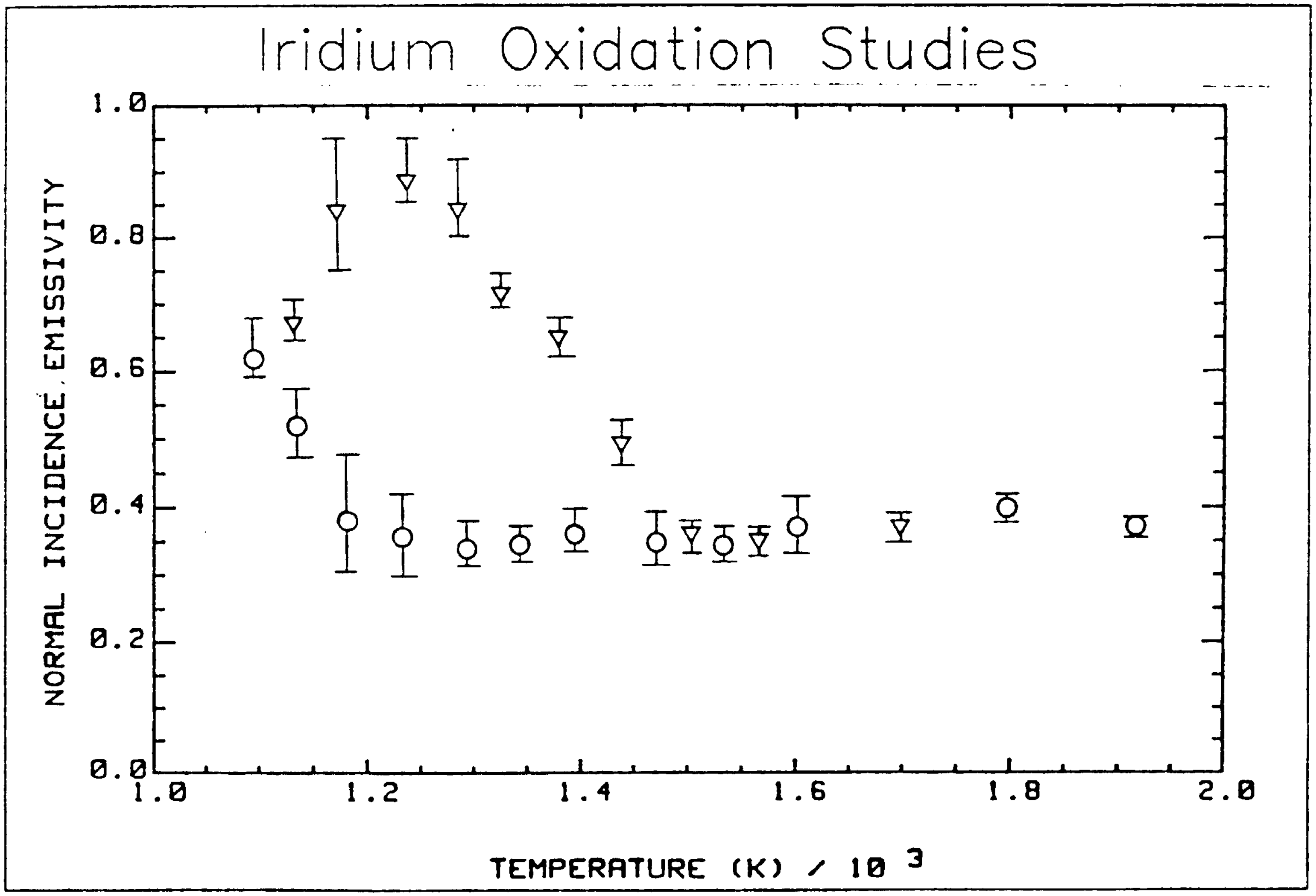


Normal incidence spectral emissivity of liquid aluminum as a function of temperature at 633 nm (□).

SOLID AND LIQUID SILICON



NORMAL INCIDENCE SPECTRAL EMISSIVITY OF SOLID AND LIQUID SILICON AS A FUNCTION OF TEMPERATURE AT 633 nm (□). LITERATURE DATA INDICATED BY (+). MELTING POINT INDICATED BY ARROW.



Oxidation hysteresis of iridium reprsenting the average results of experiments in air, 10% O_2 – Ar, and 30% O_2 – Ar taken during a cooling (O) and heating (∇) cycle.